CS449 - ASSIGNMENT 6 REPORT - GROUP 18

Zeki Karamuk – 22496 **Erdem Özcan – 29225**

Mustafa Adnan Arasan – 29413 **İlyas Yeşilyaprak – 29294**

1. Overview of the system

The program that will be explained is an interactive gesture-controlled application called Fruit Orchard. This system is designed as a game and educational tool to demonstrate how hand gestures can interact with a graphical user interface (GUI).

1.1. Gesture Recognition

By using Mediapipe's hand solutions the program detects hand gestures and gives appropriate output. In Fruit Orchard, users interact with the system with using their hands. The gestures in the system trigger different functionalities.

1. Navigate the screen (scrolling left, right, up, and down) using a One Finger Gesture.
2. Select and drag fruits to a basket using the Two-Finger Gesture.
3. Quit the application using a Three-Finger Gesture.

1.2. Methodology

First of all, after implementing the Fruit Orchard game, as a team we have played the game and got familiar with the Fruit Orchard game. As a team, we have conducted different tests and task scenarios to take into consideration edge cases.To detect usability issues in the system, we have

determined a test scenario that could be test with different users. By testing the system with a persona that has similar features we have detected possible usability issues and also we have measured different factors such as performance, efficiency and satisfaction of the user.

To test our system, we have prepared a persona and picked users that have no prior experience with gesture-based interaction applications. And also we have balanced our persona by selecting the users with different gender and background information. Before the test is started we have collected demographics data from each user to help balancing our persona. The persona that we created have some key characteristics. All test users study in a University and their age is in range between 20 - 25. Although some people's department is computer engineering, no user has had experience with a gesture-based application.

1.2.1. Test Procedure

Before the test, all of the users are informed about specific hand gestures that trigger functionality. We have stabilized the test environment conditions to get more accurate results. Each participant conducted the test separately in an isolated and quiet environment. And also all participants used the same device which ensures consistency. During the test, we have recorded their actions to make quantitative and qualitative analyses. After the test process is done, we asked some questions about their experience with the Fruit Orchard application to form qualitative data. After verbal communication, we asked them to fill out the questionnaire that we created to gather quantitative data.

1.2.2. Task Procedure

After conducting the pilot test we have determined a test scenario that all users will try to complete it. After the test starts, the user should click the play game button with using two finger gesture. After that user should read the instructions and by using one finger gesture they have to scroll down,up,left or right and find apples. After that, they should pick the apple using a finger

gesture and drag it into the basket to increase their score. Users should find and pick 5 apples and drag them into the basket and increase their score to 5. All users have 6 minutes to complete the task.

ID	Gesture	Description	Expected Action
1	Two-Finger Gesture	Click the "Play Game" button to start the game.	User uses the cursor control mode to press "Play Game".
2	One-Finger Gesture	Scroll to read the instructions on the instructions page.	User scrolls up, down, left, or right to view all instructions.
3	One-Finger Gesture	Scroll to locate apples on the canvas.	User scrolls in all directions to find apples.
4	Two-Finger Gesture	Pick the apple and drag it toward the basket.	User selects an apple and moves it into the basket.
5	Two-Finger Gesture	Repeat the apple-picking task for 5 apples to increase the score to 5.	User successfully drags 5 apples into the basket.
6	Three Finger Gesture	Close the application when the task is finished.	User closes the GUI application.

Table 1: Task Procedure Table.

1.2.3. Context

As mentioned above, all of the tasks are done with different users in a quiet and isolated environment. All of the users used the same application and the same computer to ensure consistency. Sessions are recorded to determine the usability of the system.

1.2.4. Tool

All users are used the same application and same computer which are specified below:

Device: Macbook Pro 13 2020

Processor: Intel Core İ5

RAM: 8 GB

Screen Size: 13 inches, Full HD

Webcam: Built-in 720p HD Camera

Software:

Fruit Orchard Application: Gesture-controlled GUI game.

Mediapipe Hand Solutions: For detecting hand gestures.

OpenCV: For capturing and processing video input.

Recording: OBS Studio for screen and webcam recording.

1.2.5. Users/Persona(s)

1.2.5.1. Person 1:

- **Name:** Selin Tıraş
- **Age:** 23
- **Gender:** Female
- **Major:** Industrial Engineering
- **Education Level:** Undergraduate
- **Hobbies/Interests:** Yoga, Hiking

2. Demographics

- Background: Turkish
- Technology Exposure: General user
- Experience with Gesture-Based Systems: None
- Familiarity with Games: Very little

3. Personality

- Key Traits: Curious
- Preferred Learning Style: Hands-on

4. Goals and Motivations

- Primary Goal: To have a new experience on the hand gesture based system
- Motivations: She is curious about new technologies that he is not familiar with.

5. Behaviors

- Interaction with Technology: Submitting university homeworks, Studying classes
- Reaction to New Systems: Excited

6. Challenges

- Potential Frustrations: None
- Barriers to Success: Lack of prior experience with similar systems

7. Testing Context

- Preferred Environment for Interaction: Quiet
- Device Familiarity: First time experiencing hand-gesture based interaction

8. Quotes and Insights

- Key Quote: One day or day one!

1.2.5.1. Person 2:

- **Name:** Halil İbrahim Koç
- **Age:** 24
- **Gender:** Male
- **Major:** Finance
- **Education Level:** Masters
- **Hobbies/Interests:** Basketball, Late night british döner

2. Demographics

- Background: Turkish
- Technology Exposure: Experienced user
- Experience with Gesture-Based Systems: None
- Familiarity with Games: Moderate

3. Personality

- Key Traits: Systematic
- Preferred Learning Style: Hands-on

4. Goals and Motivations

- Primary Goal: To have a new experience on the hand gesture based system
- Motivations: To learn new fields about technology

5. Behaviors

- Interaction with Technology: expanding his vision with learning Machine Learning concepts
- Reaction to New Systems: Excited

6. Challenges

- Potential Frustrations: None
- Barriers to Success: No barriers

7. Testing Context

- Preferred Environment for Interaction: Quiet
- Device Familiarity: First time experiencing hand-gesture based interaction

8. Quotes and Insights

- Key Quote: Always experience new things!

1.2.5.1. Person 3:

- **Name:** Marnix Ploeg
- **Age:** 23
- **Gender:** Male
- **Major:** International Bussiness
- **Education Level:** Undergraduate
- **Hobbies/Interests:** Gym, Football

2. Demographics

- Background: Dutch
- Technology Exposure: General user
- Experience with Gesture-Based Systems: He played Kinect before.
- Familiarity with Games: High

3. Personality

- Key Traits: Hopeful
- Preferred Learning Style: Hands-on

4. Goals and Motivations

- Primary Goal: To experience to compare with Kinect

- Motivations: he is curious about technologies that he is familiar with.

5. Behaviors

- Interaction with Technology: Plays games regularly and using for school activities
- Reaction to New Systems: Excited

6. Challenges

- Potential Frustrations: None
- Barriers to Success: None

7. Testing Context

- Preferred Environment for Interaction: Slightly quiet
- Device Familiarity: He used to play Kinect

8. Quotes and Insights

- Key Quote: Never know without trying!

1.2.5.1. Person 4:

- **Name:** Saleh Alshurafa
- **Age:** 25
- **Gender:** Male
- **Major:** Computer Science and Engineering
- **Education Level:** Masters
- **Hobbies/Interests:** Games, coding

2. Demographics

- Background: Palestinian
- Technology Exposure: Expert
- Experience with Gesture-Based Systems: Used to play Wii
- Familiarity with Games: High

3. Personality

- Key Traits: Curious
- Preferred Learning Style: Hands-on

4. Goals and Motivations

- Primary Goal: To have a new experience on the hand gesture based system
- Motivations: She is curious about new technologies that he is not familiar with.

5. Behaviors

- Interaction with Technology: Coding everyday
- Reaction to New Systems: Excited

6. Challenges

- Potential Frustrations: None
- Barriers to Success: Having difficulty to adapt the game

7. Testing Context

- Preferred Environment for Interaction: Quiet
- Device Familiarity: He used to play Wii

8. Quotes and Insights

- Key Quote: Never Stop Learning!

1.2.5.1. Person 5:

- **Name:** Mine Ergin
- **Age:** 22
- **Gender:** Female
- **Major:** Computer Science and Engineering
- **Education Level:** Undergraduate
- **Hobbies/Interests:**

2. Demographics

- Background: Turkish
- Technology Exposure: Normal
- Experience with Gesture-Based Systems: None
- Familiarity with Games: Low

3. Personality

- Key Traits: Quiet
- Preferred Learning Style: Hands-on

4. Goals and Motivations

- Primary Goal: To have a new experience on the hand gesture based system

- Motivations: She is curious about new technologies that she is not familiar with.

5. Behaviors

- Interaction with Technology: CS major, coding, studying classes
- Reaction to New Systems: Excited

6. Challenges

- Potential Frustrations: None
- Barriers to Success: Lack of prior experience with similar systems

7. Testing Context

- Preferred Environment for Interaction: Slightly quiet
- Device Familiarity: First time experiencing hand-gesture based interaction

8. Quotes and Insights

- Key Quote: Wondering about future technologies!

1.2.6. Test Session Photos

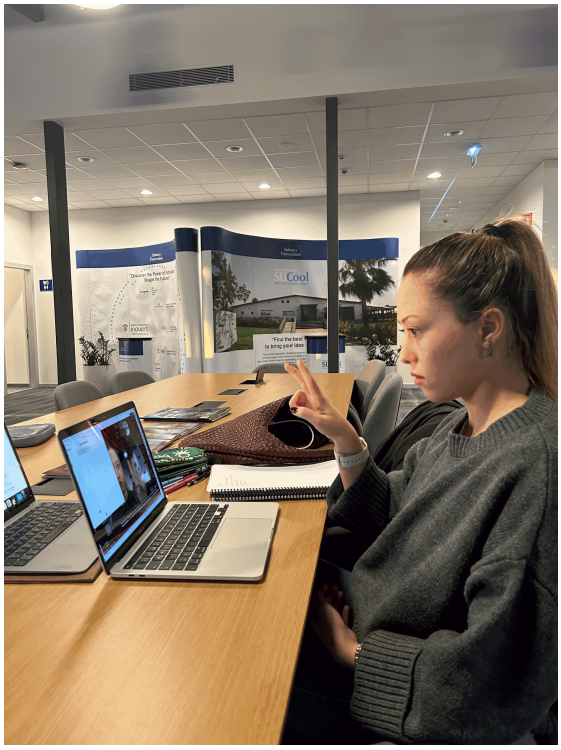

Figure 1: *An IE student experiencing the game for the first time*

Figure 2: A Finance major student experiencing the game for the first time

Figure 3: An Erasmus student from Holland experiencing the game for the first time

Figure 4: An international masters student experiencing the game for the first time

Figure 5: A female CS student experiencing the game for the first time

2. Results

2.1. During theTests Results

2.1.1. Quantitative Data

This section includes measurable outcomes and statistics collected during the tests. The users' interactions, task completions, and gestures were observed and recorded through videos while they completed the designated tasks.

Task Success Rate:

- 5 out of 5 users attempted to use the application to pick up fruits and successfully drop them into the basket using the required gestures.
- 4 out of 5 users successfully completed the task within the designated time.
- While 80% of the users completed the task successfully, 1 user could not add the last remaining fruit to the basket within the specified time and failed.

Task Attempt and Completion Time:

- The durations for completing the tasks by each user were as follows:
    - User 1: 4 minutes and 12 seconds
    - User 2: 3 minutes and 50 seconds
    - User 3: 5 minutes and 45 seconds
    - User 4: 4 minutes and 20 seconds
    - User 5: 6 minutes (unfinished).
- Average task duration: 4 minutes and 49 seconds.
- Average duration for successful completions: 4 minutes and 32 seconds.

Error Rate:

Several notable errors were observed during the tasks:

- **Unintended Actions**:
    - 1 user accidentally closed the application while attempting to interact with the system. This caused the user to restart the task and ultimately fail to complete it within the session.
- **Hand Detection Issues**:
    - Users sometimes moved their hands out of the camera's field of view without realizing it. As a result, the system stopped detecting their gestures, leading to delays as users tried to understand the issue.

- **Scroll Mechanism Misunderstanding**:
    - All users struggled with the scroll down/up/left/right mechanism because they reached the camera's detection limits. Instead of scrolling further, they had to move their hands back to the center of the camera view to trigger the scroll gesture again.
    - This caused confusion, and users spent time trying to understand how to continue scrolling effectively.

These issues significantly impacted the user experience as participants required additional time to adapt to the system's interaction constraints and camera limitations.

2.1.2. Qualitative Data

This section includes observations, user feedback, and themes derived from the tests. The focus is on identifying patterns and insights that highlight user behavior and usability challenges.

User Observations During Testing:

- All users clearly understood their tasks, which included selecting fruits and dropping them into the basket; however, they encountered challenges related to hand gestures and system responsiveness.
- **Hand Detection Issues**:
    - Users often moved their hands out of the camera's field of view without realizing it. This caused the system to stop detecting their gestures, leading to confusion as they tried to identify the issue.
    - Users spent time adjusting their hands back to the center of the camera view to reinitialize gesture recognition.
- **Scroll Mechanism Challenges**:
    - All users struggled with the scroll mechanism. When they reached the scroll boundary, they had to move their hands back to the camera's center without scrolling further, which caused delays and confusion.

    - Users spent noticeable time understanding that they needed to reset their hands for continued scrolling.
- **Task Completion Fatigue**:
    - Users experienced arm fatigue after interacting with the system for a prolonged period.
    - Some participants paused to rest their hands or shook them to alleviate discomfort.

Feedback Highlights:

- *"I didn't realize my hand went out of view, and I couldn't understand why the system wasn't working. It is annoying."*
- *"Scrolling feels a bit tricky and annoying. I thought I could keep my hand at the boundary and it would keep scrolling."*
- *"My arm feels tired after a while, but the system works fine when I'm centered."*
- *"I confused scroll and cursor movements, and since they were both close to each other, I had difficulty controlling my finger."*

Emotional Responses:

- Users expressed noticeable frustration when the system failed to detect their hands due to camera positioning issues.
- Users had difficulty switching between different gestures and had some difficulty arranging their fingers according to the other gesture.
- Most users displayed confusion when they were required to scroll and reset their hand positions.
- The initial reaction to the game was positive excitement, especially after successfully picking up the first fruit and dropping it into the basket.
- As the tasks progressed, fatigue set in, and some users showed mild discomfort in their arms.

Key Usability Challenges:

- **Hand Detection Limits**: Users struggled when their hands went out of the camera's detection range. This caused delays as they had to figure out how to reposition their hands for the system to work.
- **Scroll Mechanism Complexity**: Users did not intuitively understand that they had to reset their hand positions back to the center of the camera to scroll again. All users experienced this issue and spent extra time to resolve it.
- **Arm Fatigue**: Prolonged hand usage caused discomfort for most users, highlighting a physical usability challenge.
- **Gesture Switching Difficulty**: Users had difficulty switching between different gestures and arranging their fingers to match the requirements of other gestures. This often led to delays and confusion.

This qualitative data reveals that while users understood the task requirements, they encountered challenges with gesture detection and scroll boundaries, leading to delays and confusion. Additionally, users experienced difficulty switching between gestures and arranging their fingers correctly for different gestures, which further hindered smooth task completion. Physical fatigue from prolonged hand usage also impacted the user experience. These insights highlight the need for improved gesture recognition and clearer user guidance to reduce confusion and ensure a smoother interaction process.

2.2. Post Tests Results

2.2.1. Quantitative (Interview) Data

After completing the tasks, we asked users five questions to gather insights regarding their experiences. The responses provide feedback on key usability aspects, challenges, and areas for improvement.

1. What was the easiest task to perform during the test?

- *"It was very simple to move fruits that appeared on the same screen as the basket to the basket."*
- *"It was very simple to wait on the apple to pick."*
- *"The task of picking up the fruit and moving it to the basket was simple and didn't require too much thinking."*
- *"It was easy to pick and carry the fruit."*
- *"Carrying the fruit was very easy as it was positioned according to my hand."*

2. What was the most challenging part of the test?

- *"Sometimes my hand would move out of view of the camera and I wouldn't even notice. It was frustrating at first to figure out why it had stopped working."*
- *"Scrolling down and up was challenging because I had to reposition my hand to the center after reaching the camera boundary."*
- *"Switching between different gestures was tricky; arranging my fingers correctly took a few tries."*
- *"Understanding the scroll mechanism and realizing how it resets when I move my hand back was confusing."*
- *"I spent time trying to get my hand back into the camera's field of view after moving too far to the sides."*

3. Did you find the gestures natural and intuitive? Why or why not?

- *"I found navigating with the cursor natural, but hovering over apples to pick them wasn't intuitive."*
- *"Switching between cursor and scroll movements was not natural and intuitive, but hovering the cursor was intuitive, I can say."*
- *"Using the cursor was natural and intuitive, but it would have been more natural if a different gesture had been used instead of waiting on the fruit to select it."*
- *"Not entirely. I had trouble positioning my fingers correctly when switching gestures."*

- *“Yes, it was simple to move the cursor and wait to select items, but scrolling was a bit unintuitive and unnatural, it would have been more natural if it went where we pointed with our finger.”*

4. Were the visual feedback and instructions clear?

- *“Yes, the instructions were clear enough for me to understand what I had to do.”*
- *“Yes, the instructions were clear enough for me to understand what I needed to do, and the fact that gesture detection is visible on the side of the game made it easy to follow.”*
- *“Yes, the instructions were clear enough for me to understand what I had to do.”*
- *“Yes, the instructions were clear enough for me to understand what I had to do.”*
- *“Yes, the instructions were clear enough for me to understand what I needed to do, and the fact that gesture detection is visible on the side of the game made it easy to follow.”*

5. What improvements would you suggest for the application?

- *“Better visual feedback when the hand leaves the camera’s view, so I know what’s happening.”*
- *“The scrolling mechanism can be improved to feel smoother and more continuous, and the cursor can be made usable at the same time.”*
- *“It could become a real game with more realistic gesture choices and a nicer looking GUI.”*
- *“When switching between hand movements, more dissimilar hand movements may be preferred.”*
- *“The game screen can be enlarged. The current version was a bit small. A warning mechanism can also be added to prevent overflowing the camera border.”*

2.2.2. Qualitative (Questionnaire-SUS) Data

The System Usability Scale (SUS) was used to evaluate the usability of the application. Each user responded to 10 questions rated on a 5-point Likert scale, where 1 corresponds to "Strongly

Disagree" and 5 corresponds to "Strongly Agree". SUS scores were calculated by adjusting the responses: for positive questions (1, 3, 5, 7, and 9), 1 was subtracted from the score, and for negative questions (2, 4, 6, 8, and 10), the score was subtracted from 5. The adjusted values were then summed and multiplied by 2.5 to yield a score in the range of 0–100.

F12 =2.5*((F2-1)+(F4-1)+(F6-1)+(F8-1)+(F10-1)+(5-F3)+(5-F5)+(5-F7)+(5-F9)+(5-F11))

	A	B	C	D	E	F	G
1	strongly disagree 1, strongly agree 5	1	2	3	4	5	
2	I think that I would like to use this system frequently	1	2	1	1	2	
3	I found the system unnecessarily complex.	2	1	2	1	2	
4	I thought the system was easy to use.	4	5	4	5	4	
5	I think that I would need the support of a technical person to use this system.	5	5	4	5	5	
6	I found the various functions in this system were well integrated.	4	5	4	5	5	
7	I thought there was too much inconsistency in this system.	2	2	2	1	2	
8	I would imagine that most people would learn to use this system very quickly.	4	4	5	4	3	
9	I found the system very cumbersome to use.	2	1	2	2	2	
10	I felt very confident using the system.	3	4	3	4	3	
11	I needed to learn a lot of things before I could get going with this system.	2	1	2	2	2	AVERAGE SUS
12	SUS SCORE	57.5	75	62.5	70	60	65

Figure 6: SUS results from excel calculations as formula shown.

The results are as follows:

- User 1: 57.5
- User 2: 75.0
- User 3: 62.5
- User 4: 70.0
- User 5: 60.0

The average SUS score across all users was calculated as 65.0. This score indicates that the system achieved an acceptable level of usability; however, there is room for improvement.

It is important to note that we informed participants beforehand to provide their scores objectively and to avoid inflating results due to familiarity, as they were close acquaintances. To ensure fairness and a more balanced evaluation, participants were asked to be critical and deduct points wherever they encountered usability issues.

The SUS results provide quantitative evidence that usability enhancements could further improve user satisfaction and overall experience.

3. Discussion and Conclusion

The usability testing conducted on the Fruit Orchard application provided valuable insights into the system's performance, user experience, and areas for improvement. The testing methodology, which included task-based scenarios, quantitative data collection, and qualitative feedback analysis, revealed both the strengths and challenges of the gesture-based interface.

3.1 Discussion

The system achieved a high task success rate, with 80% of participants successfully completing all designated tasks within the allocated time. However, several usability challenges were identified, particularly in hand detection limits, scroll mechanism complexity, and physical fatigue caused by prolonged hand usage. These issues are consistent with common usability challenges in gesture-based systems, where the learning curve and environmental constraints impact user performance (Tullis & Albert, 2013).

Hand Detection and Scroll Limitations: Users frequently struggled when their hands moved out of the camera’s field of view. This caused delays and frustration as participants had to reposition their hands to reinitialize gesture detection. These findings align with the observations of Rosson and Carroll (2001), who highlight the importance of intuitive system feedback to reduce confusion in user interactions.

Gesture Complexity and Fatigue: The transition between gestures, particularly scrolling and selection, proved challenging for users. Participants expressed difficulties in adapting to the two-finger and one-finger gestures, which led to unintended actions. Additionally, arm fatigue emerged as a recurring issue, emphasizing the physical toll of prolonged gesture-based interactions. This outcome underscores the importance of designing gesture systems that account for human ergonomics and minimize user fatigue over extended periods (Tullis & Albert, 2013; Nielsen, 2012).

User Satisfaction and System Usability: The SUS (System Usability Scale) scores indicated a moderate level of usability, with an average score of 65. While this score reflects an acceptable level of usability, it also highlights room for improvement in terms of user guidance, gesture sensitivity, and overall interface responsiveness. Participants' qualitative feedback suggested the need for improved visual cues, smoother scrolling mechanisms, and clearer distinctions between gestures to enhance usability and reduce frustration.

3.2 Conclusion

The Fruit Orchard application successfully demonstrated the feasibility of gesture-controlled interaction using Mediapipe's hand solutions. Despite its innovative approach, usability challenges related to system responsiveness, gesture recognition boundaries, and physical fatigue highlight areas for improvement.

Future iterations of the system should focus on the following enhancements:

1. Improved Gesture Feedback: Providing real-time visual cues when hands move out of the camera's field of view to prevent user confusion.
2. Gesture Simplification: Redesigning gestures to reduce complexity and improve intuitiveness for first-time users.
3. Ergonomic Considerations: Introducing shorter tasks or rest breaks to mitigate physical fatigue during prolonged usage.
4. Refined Scrolling Mechanism: Enhancing the scrolling system to allow smoother and more continuous navigation without frequent resets.

By addressing these challenges, the system's overall usability, performance, and user satisfaction can be significantly improved. These findings contribute to the broader understanding of usability in gesture-based systems and highlight the importance of iterative testing and user-centered design in developing interactive applications.

4. References

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